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ABSTRACT

The concept of a chemical reaction (as opposed to physical mixing, dissolution, or change of state) is developed in this five-part unit. In addition, the ideas that chemical reactions involve the formation of new substances and that mass is conserved in a chemical reaction are stressed. Part 1 discusses unit objectives and considers teachers' views on chemical reactions. Part 2 is an 11-item instrument designed for teachers to examine their views and to determine student views before and after instruction. Part 3 discusses scientists' views of chemical reactions (and dissolving) and lists correct answers to the survey instrument presented in part 2. Scientists' views are contrasted with children's views of four common events, using comments obtained from the in-depth phase of the Learning in Science Project. Events considered include: vitamin C tablet reacting in water; precipitation; rusting nails; and dissolving. Part 5 lists a series of activities designed to build on children's views where these views are essentially similar to those of scientists, and to challenge and change children's views where these are found to be inconsistent or incompatible with those of scientists. An overall framework to the sequence of activities (in flowchart format) is included. (JN)

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REACTIONS

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WORKING PAPER No. 37

PART 1

REACTIONS

A Resource Unit for Teachers

Brendan Schollum

June 1982

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INTRODUCTION - YOUR OWN VIEWS

Many children arrive at Form 1 classrooms with high expectations of science as a subject to study. This happens again at Form 3, but for many children, classroom experiences of science do not live up to their expectations as they progress from Form 1 to Form 4. Comments such as:

> "We don't know why we are doing the experiments."
>
> "We just mucked round with strange equipment and stuff."
>
> "Only once did we get the chance to try things our way."
>
> "I have to learn it the teacher's way for exams but I think of it differently."

can be found in many classrooms.

Teachers are concerned that experiences provided in science should help children (immediately or ultimately) make sense of the world. One of the problems for teachers of the chemistry component of the Form 1-4 science curriculum is in providing suitable activities or experiences so that children make sense of many of the changes they observe, (or smell or taste) occurring in their lives. This resource unit then builds on or seeks to modify the views that children have about many of the changes they experience in and out of science classrooms.

In this Unit,

i) the concept of a chemical reaction, as opposed to physical mixing, dissolution, or change of state, is developed.[1]

ii) the idea that chemical reactions involve the formation of new substances is stressed. In particular the criteria for determining how we can know that new substances are formed (products) at the expense of the reacting substances (reactants) is emphasized. An important idea developed here is that scientists use 'tests' to determine the presence or absence of substances.

iii) the idea that mass is conserved in a chemical reaction is stressed. This is important, as often this is contradictory to children's everyday experiences, e.g. coal being burnt, rust 'eating away' metals.

Overall, we wish to stress that it is the <u>rearrangement</u> of some of the basic particles in nature (atoms) that accounts for all chemical reactions. Furthermore there exist only about 100 different atoms and it is the different <u>arrangements</u> of these basic particles which accounts for the complex diversity of the matter in the Universe.

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[1] Reactions involving <u>burning</u> are one specific important type of reaction, and are covered in detail in the Learning in Science Project (LISP) Working Paper No. 36 (<u>Burning</u>). Changes of state and the related particle motion are highlighted in LISP Working Paper No. 38 (<u>Heating and Cooling</u>).

PART 2

IDENTIFYING VIEWS

The views of changes which may or may not involve chemical reactions can be quite different from those of the scientists. Teachers need to be aware of these children's views, as well as those of the scientist, since they strongly influence the perceived significance of any learning situation.

The following survey is designed to identify the view of changes that a person holds. It can be used,

1. to explore your own view of 'changes'. Parts 3 and 4 will enable you to relate your ideas to those of the scientist and those of children.
2. to determine the views that exist in your class (both before and after teaching).

A SURVEY OF SOME IDEAS IN SCIENCE

1. When instant coffee is put in hot water it dissolves. This means:

   (a) the coffee disappears just leaving the taste.
   (b) the coffee melts.
   (c) very small bits of coffee spread out in the water.
   (d) a chemical reaction occurs between the coffee and the water.

2. When we stir coffee in water, the stirring helps the coffee dissolve. The best reason for this is that;

   (a) oxygen is added to the water.
   (b) friction causes the coffee to heat up and melt.
   (c) more water comes in contact with bits of coffee.
   (d) the smell is freed from the coffee.

3. Some shiny nails go rusty when put in or near water. Before such nails go rusty, where is the rust?

   (a) It has not formed yet.
   (b) It is in the air.
   (c) It is in the water.
   (d) It is in the nail itself.

4. When a nail starts going rusty, does the rust and what is left on the nail;

   (a) weigh more than the nail you started with?

   (b) weigh the same as the nail you started with?

   (c) weigh less than the nail you started with?

5. John heated a solid in a test-tube and found that its mass decreased. He repeated the experiment a number of times - with the same result. Which of the following would you choose as the best explanation for the decrease in mass?

   (a) The solid gave off an invisible gas during heating.

   (b) Some of the solid melted into the test-tube during heating.

   (c) Some solids change into lighter solids or liquids when heated.

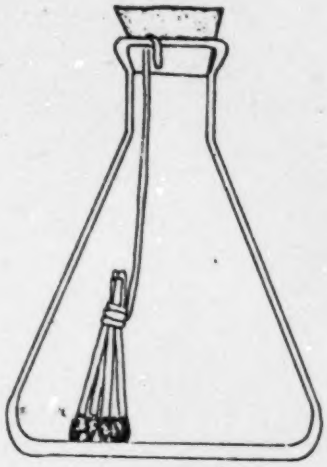
   (d) The test-tube expanded when heated and became lighter.

6. A number of matches were suspended inside a tightly stoppered flask, as shown. The mass of the flask was then found accurately. When the flask was heated, the matches caught alight and burned. The flask was then allowed to cool, and the mass was found to be:

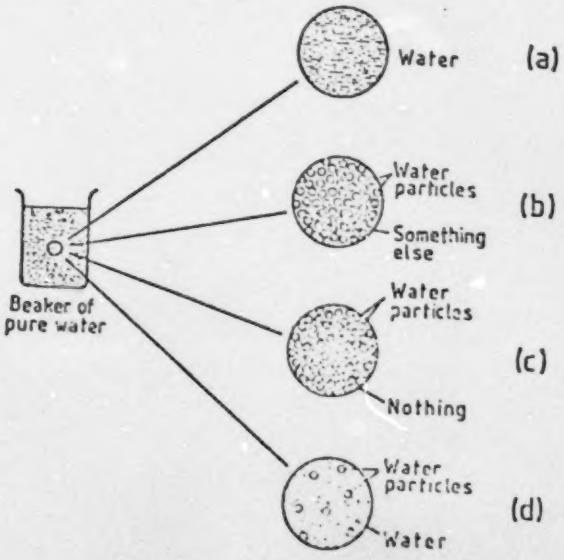
   (a) the same.

   (b) less.

   (c) more.



7. Your picture of water in its finest detail, would be most like which of the following drawings?

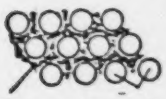


8. Your picture of the particles in Condy's crystals would be closest to which of the following drawings?

a

Purple Condy's particles

b



Purple colouring Condy's particles

c

Purple Condy's particles

d

Purple colouring Condy's particles

9. Bread turns black when overheated in a toaster. The crumbly black material is:

(a) heat which is formed.

(b) a new substance formed from the bread.

(c) what is left after heating as bread evaporates.

10. When a Vitamin C tablet is put in water many bubbles are seen. What do you think is the best reason why the bubbles formed?

(a) When the tablet was made, gas was built into it.

(b) Gas was made when the tablet was put in water.

(c) Gas was taken down as the tablet sank.

11. When a Vitamin C tablet is put in water many bubbles are seen. What do you think the bubbles are made of?

(a) Air

(b) Oxygen

(c) Carbon dioxide

(d) Some other gas

PART 3

A SCIENTIST'S VIEW OF REACTIONS

When substances are said to react, it means that there is some rearrangement of either one or both the substances and in this way an entirely new substance or substances are formed.[2] There are many examples of what happens when various things react that can be found in Resource books such as Chemical Change (Department of Education, 1980). Three common examples considered in this Unit will be used to elaborate the scientists' view of reactions.

1. A Vitamin C tablet contains substances which begin dissolving when the tablet is dropped into water. These substances come in contact with each other and react, releasing bubbles of carbon dioxide gas. This reaction and the agitation of the water helps the Vitamin C dissolve more rapidly.

2. Rust forms when iron (e.g. a nail) and oxygen (in the air or dissolved in water) and water react together to form a new substance, the rust coloured hydrated oxide of iron. For Survey Question 3, answer (a) is correct. In such a reaction the nail gains in weight. This does seem contrary to what is experienced in everyday life. However we need to distinghish between rust forming and rust flaking away from a nail. There are differences between rusting and the effects of rusting.

3. When some liquids (solutions) are mixed a runny or thick solid substance is formed in the mixture. This is called a precipitate. For example if sodium hydroxide solution is mixed with blue copper sulphate solution, a pale blue jelly-like substance is formed (copper hydroxide). Precipitates are formed when there is a strong

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[2]The words react, reacting, reaction have different meanings in different situations. Many children relate these words to mean 'instinctive movements', or 'fighting'. For example;

> "These particles are fighting ... It seems like the rain has got onto here and it's sort of fighting and it's sort of overtaking it to form this brown stuff."
> (F4 boy describing how a nail goes rusty)

As well the word reaction has a different meaning in Physics.

It is important for children to be aware that there are these different meanings in different contexts.

attraction of parts of each solution for each other. Rather than move around independent of each other, these parts link and this happens generally, as soon as the solutions are mixed. In the example above the parts attracted to each other are the positively charged copper particles and the negatively charged hydroxide particles. Other particles in the mixture, sodium particles and sulphate particles are not attracted strongly enough to link in solid form. There is a pattern to the combinations of particles in solutions which will form precipitates when mixed and many textbooks provide examples, e.g. the teachers resource book Chemical Change (Department of Education, 1980) provides activities where precipitates are formed. The problem can be that while children enjoy mixing different solutions, often coloured, they are not sure before or after the event, what they were doing and why they were doing it.

A SCIENTIST'S VIEW OF DISSOLVING

There is debate about how a scientist defines and describes the process of dissolving. From senior secondary school classes onwards dissolving can be described in terms of the bond energies involved and hence can be considered a type of chemical reaction. At the Form 1-4 level the process is simplified in such a way that tiny particles of the substance being dissolved spread out and mix with the greater number of particles of water present. But in considering this process, it is important to realise that many people do not have the view that solids, liquids, and gases are indeed made up of particles (See Heating and Cooling, Working Paper No. 38). Pure water is made up of moving particles: there is nothing in the gaps between the particles. Thus, when a substance is placed in water and does dissolve (and of course many substances do not dissolve), moving particles of water collide with the surface particles of the substance causing them to break off and spread out through the water. Such a mixture is known as a solution.

When a coloured substance dissolves, it is not the colour coming out of the substance and spreading out, but it is millions of particles spreading out. It is these particles which give the coloured effect.

SUMMARY OF SCIENTISTS' VIEWS

In summary, the important features related to things mixing together, and possibly reacting, are;

1. No possible change will occur unless the actual substances are in direct contact with each other.

2. Heating substances often causes changes to occur more quickly and to a greater extent, e.g. sugar in water.

3. In some cases it is relatively easy to regain what you started with, e.g. separating salt solutions to salt and water. The term physical change can be used in these instances where the original material continues to exist but in a different form.

4. The term chemical change or chemical reaction can be used where one or more of the substances break up or become rearranged into entirely new substances. The following types of change are possible:

i) A → B + C
e.g. sugar → carbon + steam

ii) A + B → C
magnesium + oxygen → magnesium oxide

iii) A + B → C + D
calcium + water → calcium hydroxide + hydrogen

iv) A + B + C → D
Iron + water + air → rust (hydrated iron III oxide)

v) A → B
nitrogen dioxide gas → dinitrogen tetroxide gas

The answers then in summary form to the survey questions are

1.	c	7.	c
2.	c	8.	a
3.	a	9.	b
4.	a	10.	b
5.	a	11.	c
6.	a		

PART 4

CHILDREN'S VIEWS ABOUT REACTIONS (AND DISSOLVING)

Below is a summary of children's views contrasted with the scientists' view of several common events. The first three involve chemical reactions and the fourth relates to dissolving.

Three of the four events described below to identify children's views involve substances not usually associated with science classrooms. But all four events provided insights into the variety of views held by children about any such events.

CHILDREN'S VIEWS	contrasted with	SCIENTISTS' VIEWS
1. Bubbles formed when a solid and liquid are mixed have been caused by: - some sort of air lock (p.10) - air taken down as the solid sinks (p.10)		Bubbles formed when a solid and liquid are mixed have been caused by particles of the solid reacting and forming new substances, e.g. a gas (p.5)
2. A solid (precipitate) can be formed when two liquids (solutions) are mixed because - the original substances have settled out as some sort of composite mixture of the two (p.11) - the original substances have settled out without interacting in any way (p.11) - something has settled out (p.12)		Precipitates are formed because there is a strong attraction of parts of each solution for each other (p.5)
3. Rust is a protective coating which stops the nail from decaying (p.13) Rust exists under the outer shiny layer of a nail (p.13) Rust is seen when water causes some impurity in a nail to come to the surface (p.13)		Rust forms when a nail (iron), oxygen in the air (which may be dissolved in water), and water, react together to form a new substance (p.5)
4. When a solid dissolves - it melts (p.14) - it disappears just leaving the taste (or colour) (p.15) - the taste (or colour) spreads out leaving an ampty shell (p.15)		When a solid dissolves, moving particles of water collide with the surface particles of the solid causing them to break off and spread out through the water. If the solid is coloured, millions of tiny coloured particles spread out (p.6)

Children's views[3] about these events are now described in greater detail.

4.1 VITAMIN C TABLET REACTING IN WATER

Pupils placed a Redoxon Vitamin C tablet in water and were asked to observe carefully what happened. All mentioned that they saw bubbles in the water. Two questions were then asked, and the pupils' responses explored:

A. What are the bubbles made of in your view?

Response	Total
Air	17
Carbon Dioxide	6
Gas	5
Oxygen	2
Hydrogen	1
Hydrogen & Oxygen	1
Bits of Vitamin C	1
I don't know	5

B. In your view, where did the bubbles come from"

The views expressed by the pupils regarding the origin of the bubbles were of three categories.

1. The bubbles resulted from a chemical reaction between the tablet and the water. (F2, F3, 4 x F4, F5, 2 x F6, 2 x T.C.)

For example:

> "When it hit the water it started to disintegrate. It gave off a created gas. ("Can you put it another way?") Starts them off ... when the tablet hits the water there is a certain substance in there that creates the gas." (F4)

The fact that the pupils had a view sympathetic to the idea of chemical change did not necessarily mean that they had a typical scientific view. For example;

> "The tablet is reacting with the water, splitting up the hydrogen and the oxygen. That's turning them into their gas forms and the gas comes out the top." (F6)

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[3] The children's views referred to in PART 4 of this paper are described in greater detail in The Learning in Science Working Papers Particles, No. 18, John Happs; Physical Change, No. 26, Mark Cosgrove and Roger Osborne; and Chemical Change, No. 27, Brendan Schollum. For each paper, some 40 pupils ranging from 10 years old (S4) to Form 7 were interviewed. As well several Primary Teachers College students were interviewed.

2. The bubbles are caused by a physical change within the tablet when it is placed in water. Various causes were given. For example:

> "... it must have been some sort of airlock in it and the air that's in it forces itself out and up to the top." (F3, also 2 x F2, 3 x F3, 2 x F4, 1 x F5, 1 x F6)
>
> "When they made the tablet they put little air bubbles in ..." (F2, also 2 x F2)
>
> "They come from the tablet making air under water." ("How does the tablet make air under water?") "I don't know unless the room it took up went up in bubbles." (F4)

3. It was not known how the bubbles were formed.

Despite gentle coaxing, five pupils (1 x F2, 2 x F3, 2 x F5) had the view that the bubbles formed in some unknown or mysterious way.

4.2 PRECIPITATING

Students were shown samples of solid sodium chloride and lead nitrate, which were then dissolved separately in water. The resulting solutions were later mixed together to form a precipitate of lead chloride.

Discussion was directed towards the individual solids, the two solutions and the precipitate.

The following analysis of responses highlights some of the more typical ideas that students offered concerning precipitation.

Asked what they considered had happened when the two clear liquids were mixed together and a white precipitate formed, only 5 students (1 x F6, 4 x F7) used the word 'precipitate' in their response. Many students were happy simply to describe what they saw happening, but others used scientific words as well:

"The two solids have made the water murky." (F4)

"Real murky water." (F3)

"It's gone into a milky solvent." (F3)

Through questioning students about what they had seen happen the following views were apparent:

View 1: A new substance has formed (S4, F2, 3 x F4, F5, F6, 3 x F7)

The precipitate was seen to be a new substance (which was neither lead nitrate nor sodium chloride) by 10 students. Of these students the precipitate was correctly identified by 4 people (1 x F6, 3 x F7) although a scientists' view of the mechanism behind precipitation was expressed by only one student (1 x F7).

View 2: The substances have settled out as some sort of composite mixture of the two (2 x S4, 4 x F2, 1 x F3, 1 x F4, 2 x F5)

Ten students thought that the sodium chloride and lead nitrate simply joined together in some way and settled out without forming any new products.

"The particles joined up again and they went straight to the bottom and just stuck there." (F4)

"They just joined together again." (F5)

View 3: The substances have just settled out (S4, F1, 5 x F3, 2 x F4, F5, TC)

These eleven students felt that the sodium chloride and lead nitrate settled out without interacting in any way.

"The heavy solids sank to the bottom." (F1)

"Well, the particles seemed to be undissolving again or coming back together." (F5)

View 4: Something's settled out (F2, F3, F4, F6, 6 x F7, 2 x TC)

The remaining 10 students tended to view the precipitate as consisting of only one solid but they were unsure what the precipitate was or how it was produced.

> "Some of the particles that haven't reacted." (TC)

> "I think the nitrate part has dissolved. I can see the lead doesn't completely dissolve." (TC)

In summary about 50% of students did not envisage a reaction of any sort and, to some older students, it was quite clear that no reaction had occured. For example,

> "If those two (sodium chloride and lead nitrate) had reacted, it would have gone clear." (F7)

4.3 RUSTING NAILS

A shiny nail was shown to each pupil. A rusty nail was shown also. It was explained that the nail had been shiny too, but had been placed half submerged in water for a week. Everyone mentioned that it had rusted or was rusty as well. Three sixth formers said initially that the nail had oxidised. Questions such as "What do you mean by rusted?" (or rust, rusty, oxidised), "What is your view of what has happened?" were asked. The responses led to questions such as "What is your view of how the rust got there?", "What is the browness?".

The prevalent views were these:

View 1: Rust occurs as a result of chemical change (F3, F4, F5, 3 x F6, 2 x TC)

Sometimes just water and the nail were seen to be the active agents in the rusting process. Sometimes oxygen (from the air, or dissolved in water, or as part of the water molecule) and the nail were seen to be the agents. Or all three substances, water, oxygen and iron were seen to be involved. The views were expressed in a variety of ways. For example,

> "The water is taking a part of the iron which allows the iron to remain solid. The water forms another sort of compound which has the properties which the iron needs to remain in its normal charged state ..." ("Where's the oxide come from?") "It's part of the iron itself. It's normal iron until it loses the charge and it becomes something new which doesn't have the properties of iron and which we know as rust." (F6)

"Water and air have combined and reacted against this nail and it's going to rot." ("What is rust?") "Rust is the form of the chemical reaction after the nail has been taken apart by the rain." (F4)

View 2: Rust is just a coating (F2, F3, 2 x F4, F5)

It can be a protective layer which stops the whole nail from decaying. For example,

"The water eats away at the metal and the nail forms a protective coat to stop the whole thing decaying." (F2)

"Rust is a sort of a chemical. It breeds in dampness. It's in the air all the time and when any steel is damp or anything, it spreads all over it and breaks it down ... it's sort of a fungi." (F4)

View 3: Water plus some impurity in the nail causes rust (3 x F2, F3, F4, F6)

When the nail is put in water, the impurity comes out and rust results. For example,

"Water got into the steel and it has taken some stuff out of it and made the steel go like that and it weakens the steel. The water got into the paint and the ingredients of the steel." (F3)

"The water reacts with the air and with an impurity within the nail." (F6)

View 4: Rust appears once the shiny outer surface of the nail is removed (F1, 2 x F2, 4 x F4, F5)

The view of this group is that rust is actually present under the shiny surface and it becomes apparent once the nail is soaked in water. It seems that the children with this view are considering the peeling of, say, chrome bumpers, revealing rust underneath.

"It's actually under the nail. It's been painted. It had a solid coat over it. I'm not sure what the silver coat is the silver coat was worn out and the rust has come out underneath. When you put something like this in water it expands and just floats apart and this has got very soft and peeled off." (F2)

View 5: Rust is the result of water eating away at the nail (3 x F3, F5, F6)

The view of this group was that the water 'eats' away at the nail, especially the surface layer. For example,

> "Water is eating into the nail and the nail would eventually disappear over a period of time." ("Would you be left with nothing?") "Well, not much anyway." (F6)

4.4 DISSOLVING

Pupils were invited to stir a teaspoon of sugar into a cup of hot water. The focus question was "What happens to the sugar?" A summary of the responses that were made is given.

"What happens to the sugar?"

View 1: It melts (4 x F1, 3 x F2, 3 x F3, F4, F5, F6)

> "When it gets into the water it kind of melts down ... and then it dissolves into the water."

LATER "It is just how I think about it." (F1)

> "Um ... because the sugar has a large surface area, when it's put in the hot water, ah melts it quicker, and then it just dissolves into the solution." (F6)

View 2: It is broken up: gets smaller and smaller, fades, disappears (S2, 4 x F1, 3 x F3, 2 x F4, 2 x F5)

> "It goes to the bottom of the cup ... then it kind of fades." (S4)

View 3: It dissolves, makes a solution (5 x F1, 4 x F2, 6 x F3, 3 x F5, 5 x F6, 2 x F7)

> ("What does dissolve mean to you?") "Oh, if you put something with another thing they both join together ... it's just got rid of all the lumps and gone with the water." ("Is it still there?") "Yes, but you don't see it because it is all mixed in ..." ("Some things don't dissolve?") "Like a stone cause it's a hard substance." (F3)

View 4: Particles are involved (2 x F3, 2 x F4, 3 x F5, 5 x F6, 2 x F7)

> "They become so tiny it's just mixed through ... as simple grains." (F3)
>
> "Well ... it doesn't actually dissolve ... it just gets broken up ... into such tiny ones that you can't see it anymore." (F5)
>
> "The sugar is dissolving ... the compounds are broken down into molecules." (F7)

View 5: Heat breaks it down (2 x F2, 3 x F3, 2 x F4, 2 x F5)

"The hot water is melting the sugar ... breaks into tiny pieces and dissolves the water because of the heat." (F2)

"Um ... maybe the heat of the water makes the molecules inside the sugar move further apart." (F4)

View 6: There is nothing left but the taste (2 x S4, 2 x F2, 1 x F4)

"The sugar is not there but the taste of the sugar is there."

This last view relates to ideas about the colour and smell held by some children. To some children the colour comes out when a coloured substance is dissolved. These children have the view that the colour comes out of a crystal, for example, before the crystal actually starts breaking up or dissolving. They imply that we see the colour spreading out in a liquid rather than the effect of millions of tiny particles spreading through a liquid producing the coloured effect. Similarly we have found children who think that when camphor is heated the smell comes out. This is not associated with tiny pieces of camphor. The smell released is independent of the camphor, in their view.

CONCLUSIONS

From these findings and from classroom observations, it is possible to recognise the following explanations of chemical reactions (other than the scientists' view).

1. The 'Conglomerate' View

All the reactants join up, a bit like pins to a magnet. This view is common even with F6 pupils and often shows up in 'equations' of the type

$$Mg + H_2SO_4 \rightarrow MgH_2SO_4$$

with assorted charges scattered about for respectibility.

2. The 'Favourable Circumstance' (or 'bear in the cave') View

That which shows up in a chemical reaction as products was really hiding in there all along and when conditions are right it shows itself (like rust from nails).

3. The 'It's Magic' View

It's sort of magic - anything could happen once different chemicals "set each other off". No pattern is seen. Even among sixth formers there are some who will happily propose that Mg and H_2SO_4 might produce CO_2 ... or anything else for that matter. Form 3 pupils are not at all upset when lead oxide changes into "mercury" on heating with charcoal, etc.

PART 5

SUGGESTED TEACHING ACTIVITIES

5.1 INTRODUCTION

The activities of this unit are planned to build on children's views where these views are essentially similar to those of scientists', and to challenge and change children's views where these are found to be inconsistent or incompatible with those of scientists.

The theme of the unit is "reactions" and the activities include phenomena which enable ideas to be linked both to everyday experiences and to new experiences.

The activities are designed so that the teacher can,

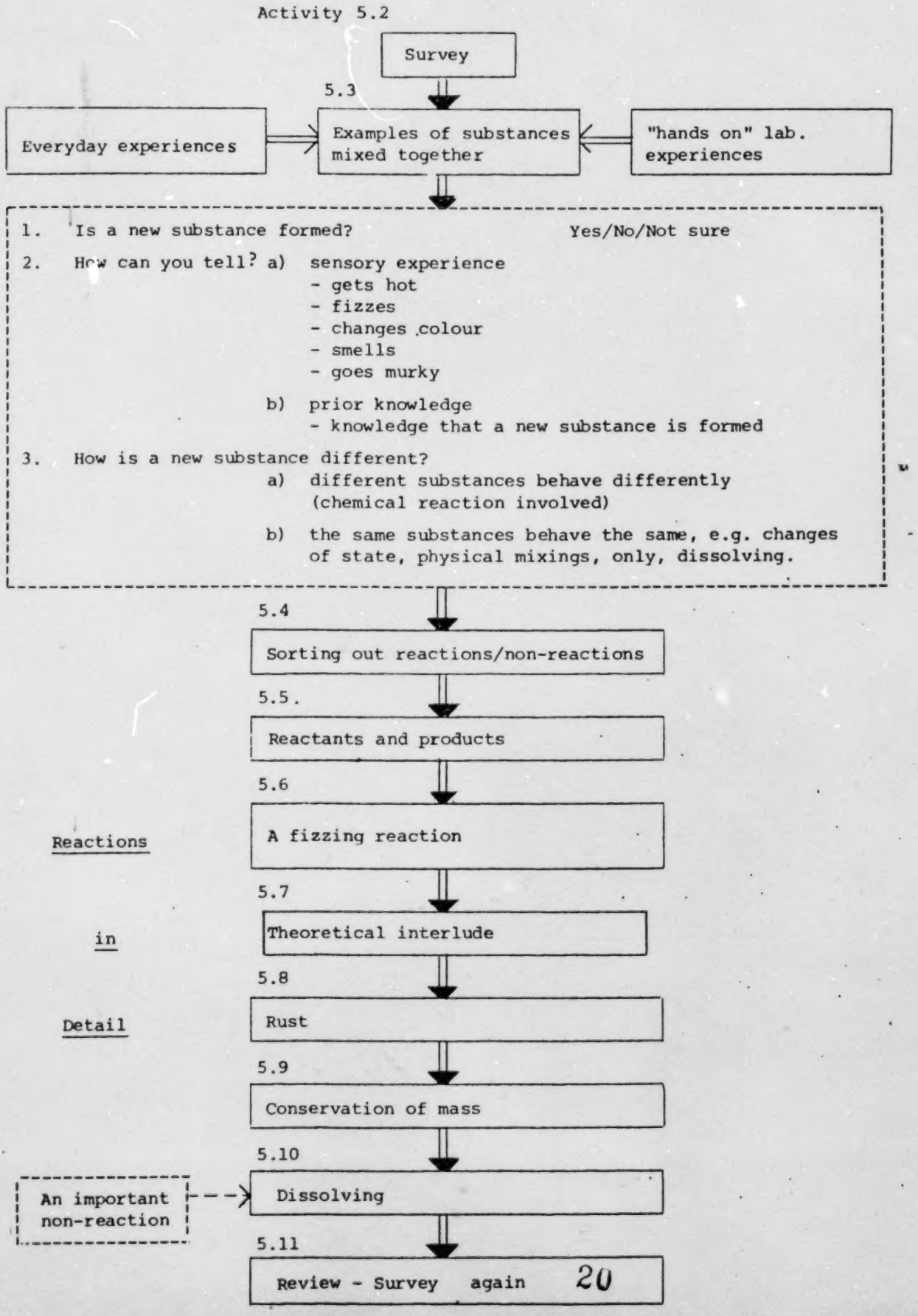
- establish the children's views
- challenge the children's views
- if necessary, and where considered appropriate, shift the children's views towards those of scientists.

Through these activities it is hoped that children will,

- clarify their own view
- consider the usefulness of their own view
- consider other views in terms of intelligibility, plausibility and usefulness
- if appropriate change their view through reason or experimentation.

Table 5.1 provides an overall framework to the suggested sequence of activities.

TABLE 5.1: OVERALL FRAMEWORK TO THE SEQUENCE OF ACTIVITIES



5.2 THE SURVEY (p. 2-4)

Purpose: Find out views about changes.

Teacher: Teachers need to know the range of views held by individuals in their class. Such knowledge will assist decision making relating to

i) appropriateness of activities

ii) grouping of pupils

iii) impact of the programme on pupils' views

Activity: Each pupil should attempt the Survey (p. 2-4)

Pupils: Pupils need to see the activity as enabling them to

i) clarify the views they hold about the topic

ii) become aware of alternative viewpoints.

NOTE: Teachers using this Unit have found it useful to get each pupil to complete two copies of the answers, one to hand in and the other to keep as a personal record (in their own science exercise books). A hand count of responses to some questions will show pupils the variation in thinking in their class.

5.3 MIXING THINGS

Purpose: To find out what sort of things can happen when you mix two substances together.

Teacher: The purpose of this activity is to provide some common experiences of things mixing together and to establish that there is a wide range of possible outcomes. These findings are to serve as the basis for class discussion and further activities.

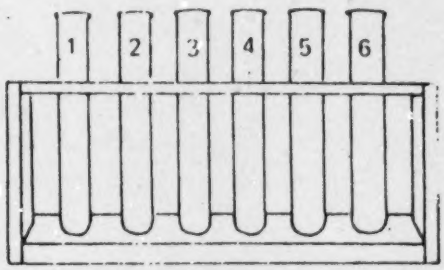
Pupils: Pupils need to appreciate the purpose of this activity and why they are doing it. They also need to appreciate why it is desirable to write out a purpose and to record their results in a table such as the following.

	Substances Mixed	Observation	Was a New Substance formed?*
1.			
2.			

* Yes/No/Not Sure etc.

Teacher: Start with everyday experiences (e.g. cordial and water, fertilizer and soil, two Araldite glues ...) work through the examples so that pupils understand the task. Then give three or four more (e.g. coffee and water) and ones that the pupils suggest. Then provide materials for six or so 'lab' mixings. Among the combinations that do react, try to include colour changes, a fizzing reaction and a precipitation.

Examples: Magnesium and dilute acid
Zinc and dilute acid
Vinegar and baking soda
Sodium hydroxide (aq) and phenolphthalein
Sodium hydroxide (aq) and cobalt chloride (aq)
Starch and iodine solutions
Sodium carbonate (aq) and copper sulphate (aq)
Copper sulphate (aq) and aqueous ammonia



Also

- include examples where the reactions are not obvious e.g. dilute acid and sodium hydroxide (aq. or a pellet)
- include examples where there is no reaction, e.g. sugar and water, salt and sugar, copper II sulphate (aq) + dilute acid.
- teacher demonstrations which may be useful during discussion, e.g. copper and conc. nitric acid (care: nitrogen dioxide is toxic)

There may well be a wide variety of observations, even for the "same reaction" and much disagreement about whether a New Substance has been formed or not.

Some things which might happen are:

- nothing at all
- something does, but it isn't obvious (e.g. acid + base)
- change could be very slow but occurring
- change may need heat or an electrical effect to make it go
- heat may be released
- reaction may cease as one reactant is consumed

Discussion should lead towards the question:

How do we know if a new substance forms?

Some ideas pupils might suggest:

- it is just obvious (so it is, sometimes!)
- it gets hot
- it fizzes
- the colour changes
- there is a new smell
- it goes murky etc, etc.

Exceptions to all of these can be produced, but in MOST cases they point to a chemical reaction rather than a physical change.

Introduce to pupils the idea that when a new substance or substances are formed chemists consider a chemical reaction has occurred.

Use the following activity to give further experiences and to provide an opportunity for pupils to develop a meaning for the terms chemical change or chemical reaction.

5.4 REACTIONS AND NON-REACTIONS

Purpose: To practise sorting out chemical reactions from non-reactions.

Teacher: A large number of examples are given here, most of which result in observable changes. However, many do not involve the formation of new substances. Work through several examples orally gathering a range of views about why pupils decided in particular ways. Notice that there are now examples used where only one substance is apparently involved. Ask pupils to leave the right hand column empty till after the class discussion and if required till after the following activities.

Pupils: Need to understand what they are doing and why they are doing it, including why they should write a purpose such as the above and tabulate their findings in a table like the one given below.

Example	Is it a chemical reaction? (Yes/No/Don't know)	Why I think that way	Final Class Decision
1. water boiling			
2. an egg cooking			
3. iron rusting			
4. a match burning			
5. the wire of a toaster element heating			
6. toast burning			
7. salt added to water			
8. a wet towel drying			
9. coal burning			
10. water freezing			
11. salt and sugar mixing			
12. food digesting			
13. curtains fading			
14. dynamite exploding			
15. milk turning sour			

Discussion: Pupils should be involved in whole class or group discussions of the reasons why pupils think new substances form, or are not formed, and hence whether there is, or is not, a chemical reaction involved. It should be brought out in the discussion that such a reaction may sometimes occur even though we cannot detect such a change with our senses. We may need to use other substances to test that the substances we started with (reactants) no longer exist and that new substances (products) have been formed. One of the important tasks of chemists (people studying chemistry) is to carry out tests on substances.

5.5 REACTANTS AND PRODUCTS BEHAVE DIFFERENTLY

Purpose: To show how the reactants and products of a chemical reaction behave differently using two examples.

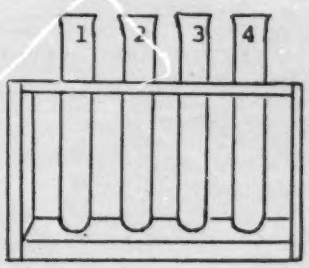
Teacher: Careful organisation is required for this activity to avoid confusion, the activities should not be hurried.
Dilute hydrochloric acid would be a suitable acid to use.

Pupils: Pupils need to appreciate the purpose of the activity and the reason for the activities proposed. Discuss the desirability of recording the purpose and tabulating the results in a table such as the one below.

Mix together ½ teaspoon iron filing and ½ teaspoon of sulphur on a filter paper. Put the mixture in 2 test tubes (1 & 2) Put a small amount of magnesium ribbon in test tube 3. Have tongs ready to heat the other portion of magnesium ribbon in a bunsen flame.

	Test Tube	Task	What I saw (sensed) happening	Why I think it happened
a)	1	heat the iron/sulphur mixture		
	2	add acid to the iron/ sulphur mixture (and gently heat)		
	1	add acid to what is in the test tube 1 when it is cooled; gently heat		
b)		using tongs, heat magnesium ribbon		
	3	add acid to a little magnesium		
	4	add acid to what is left when the magnesium is heated		

Teacher: The distinctive smell of hydrogen sulphide is a clear indicator that a reaction has taken place.



5.6 VITAMIN C TABLETS AND WATER

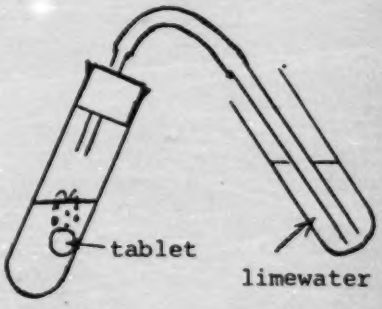
Purpose: To find out if there is a chemical reaction when a Redoxin Vitamin C tablet is put in water.

Teacher: Before commencing this activity you may find it helpful to check Section 3.1. Introduce the topic by dropping at least 1 Redoxin Vitamin C Tablet in a glass of water. Focus children's thinking by asking questions such as:

1. What do you notice?
2. Where do you think the bubbles come from? (Refer to Survey, Q.10-11).
3. What do you think the bubbles are made of?

Pupils should then re-examine the phenomena. Emphasize that they will need, this time, to make careful observations. Encourage pupils to make a detailed description of their perceptions, in particular with respect to the above focus questions. If possible, through discussion, establish on the blackboard the range, type and prevalence of the pupils' views with respect to the focus questions.

Discussion: It may be that the majority of pupils think the bubbles are made of air. If so develop the idea that we can test for the gas coming off. If the gas were oxygen, a glowing splint would relight (the scientists' test for oxygen). If the gas was carbon dioxide and was bubbled through lime-water, then the lime-water would turn milky.



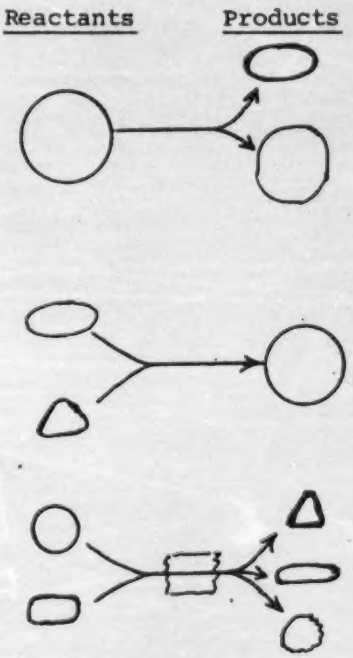
Carry out the demonstration again twice using a tablet in each case. Test for each gas.

From this and answers given in Q.1 develop the idea that at least one new substance has been formed from the contact between the tablet and the water. Anyone tasting the remaining liquid would recognise that other substances (including Vitamin C) had been left dissolved in the water. Conclude also that it would be extremely difficult to reform what we started with. The final point is another good indicator that a chemical reaction has occurred.

5.7 THEORETICAL INTERLUDE

It may be appropriate at this stage, or later, depending on the class and their background to introduce a particle (atom) model for chemical change. Chemists consider that everything is made up of basic particles (called atoms) and different substances have different groupings of these basic particles. In a chemical reaction the way these atoms are grouped together is re-arranged to from new groups. These new groups make up new substances.

There are three main ways in which particles can behave in a chemical reaction.



1. These particles, which consists of a number of basic particles, can break into smaller particles, e.g. sugar heated forms black carbon and steam.

2. Particles can join together to make bigger particles, e.g. magnesium and oxygen form white magnesium oxide.

3. Particles can collide and break up to form two or more different particles, e.g. coal and air (oxygen) form carbon dioxide, steam, and ashes.

In all cases the substances formed behave differently from the reactants.

5.8 RUST

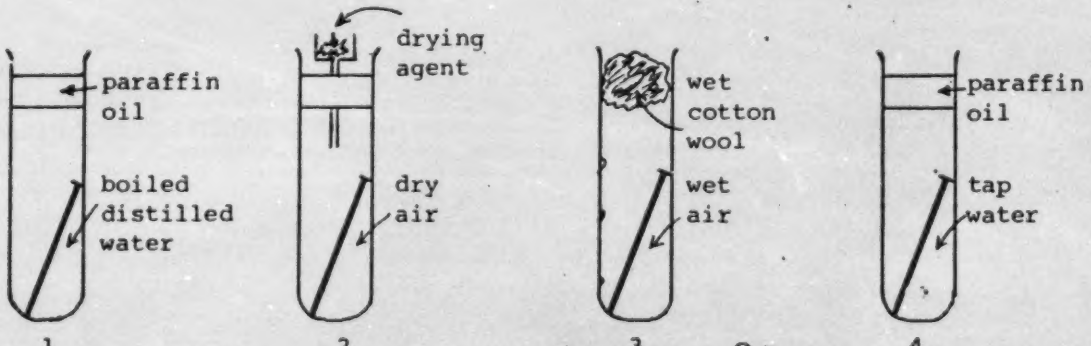
Purpose: To find out what happens when a substance rusts.

Teacher: This activity has been used by teachers to clarify for pupils what rust is and how rusting occurs (see p. 8). As a pre lesson task pupils might be required to bring some object which they consider is rusting (e.g. nail, tin can, etc.) to class. Objects such as these can provide the introductory context for the activity to follow. Pupils can explain where rusting objects are found. Why rust is of concern. What people do to stop rust.
The lesson might then focus on the following questions,

	Question	What I think	What our group thinks
1.	What is rust?		
2.	How is rust formed?		

Discuss the ideas pupils have about how rust is formed. Where possible get pupils to suggest how they might test out their ideas. If pupils suggest air and water might be involved, get pupils to suggest how this might be investigated. Let pupils design an experiment which they consider would test out various possibilities.

Discuss the designs suggested by various groups of pupils. Collectively, with teacher input, pupils may get around to setting up a full variety of conditions as exemplified below. However, at least initially you as the teacher may feel that a more limited and possibly inadequate design, but at least a design the pupils have invented themselves, may be worth pupils spending time on.



Pupils might like to design and carry out an experiment to test whether or not a nail, as it becomes rusty, weighs more or less than it did when it was shiny. They could predict beforehand what they considered would be likely to happen.

If they need some help here are two possible investigations,

i) Weigh out 10 nails on a filter paper (or cotton wool). Record the weight. Pour a little water over the nails and filter paper. Leave in a place where there is no draught, or cover with a large beaker. After 2-3 days make sure filter paper is dry and weigh it and nails again.

ii) Do the same but use steel wool on a filter paper. Weigh the steel wool, then wet it and leave for 2-3 days. Weigh it again, once it is seen to be dry.

N.B. Careful weighing is required!

Discussion: This should lead to a discussion of what has happened when something rusts. Point out that the everyday views of rust ("rust eats away", "rust - the car cancer" or "rust seen once the chrome layer of a bumper peels off") are sensible but the scientists' view is ...

5.9: CONSERVATION OF MASS

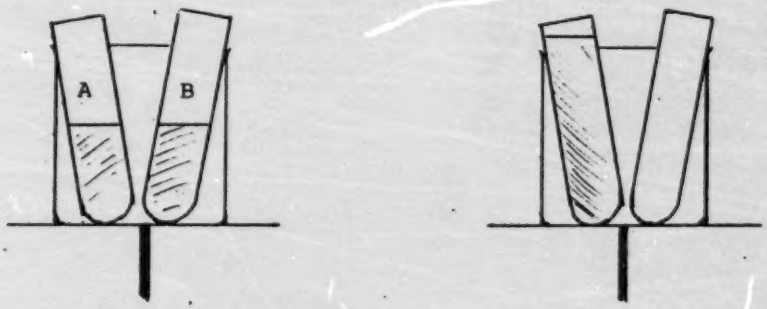
Purpose: To find out if the mass (or weight) changes in chemical reactions.

Teacher: This activity relates to questions 4-6 of the survey. Several examples are possible to illustrate that mass is conserved in chemical reactions even though often there is an apparent mass gain or loss. These reactions outlined are best done as demonstrations with time given to fill out responses before the final weighing in each case.

Pupils: Need to understand the purpose of the experiment and the point in completing a table such as the following. They might then copy purpose and table into their books.

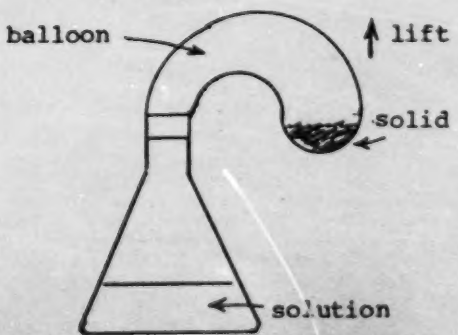
	Is a new substance formed?	Do you think the amount of matter has changed?	Why do you think that way?	Experimental Results
a) Solution A mixed with Solution B				
b) Substance A mixed with Solution B				
c) Iron rusting				

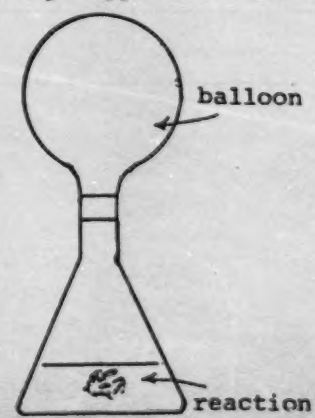
Teacher: a) Select two solutions that will form a precipitate. You may like to do this with several different combinations. Weigh 2 containers of reactants; mix, then have pupils fill out section a) of table above. Discuss responses before replacing on balance.



b) Repeat for a gas-producing reaction, e.g. carbonate and acid. If the gas is allowed to escape there will be an apparent weight loss.

Pupils can be asked how we could do it differently to contain the gas formed. Pupils are likely to suggest putting a lid on the container. Further discussion of practicalities might well lead to an appropriate idea being suggested. For example using a balloon (see below).





5.10: DISSOLVING SOLIDS: A NON REACTION

Purpose: To think about what happens when solids dissolve and whether this is a chemical reaction.

In this activity we want pupils to

i) re-experience familiar examples of dissolving (e.g. coffee, salt) and experience a possibly less familiar example (Condy's crystals),

ii) think about how they view what is happening and why it happens,

iii) listen to the viewpoints of other pupils, and, if necessary if the scientific view is not presented by other pupils, your view as a scientist or science teacher,

iv) to think about the various views which seem the best view, and why,

v) where appropriate design and carry out a critical test to establish which view is best,

vi) to carry out further activities to help them establish familiarity with new views that they have acquired.

Specific Activities (a guide)

Each group might make a prediction about what they think is going to happen when each of the solids is placed in water. Encourage pupils to think beyond just the words "it will dissolve". Discuss some of these predictions briefly before pupils carry out the activity so that they will focus on careful observation which relates to their predictions.

Ensure that pupils do record what they see as the purpose of the activity and record their thinking, possibly in a table such as the following.

	What I think will happen	What did happen	Why I think it happened
coffee mixed with hot water			
salt mixed with hot water			
a Condy's crystal mixed with water			

Discussion: The discussion might first focus on the differences between prediction and observation. Where pupils' differences lead to investigable problems pupils who are interested should have the opportunity to design and carry out investigations to follow this up.

The discussion might then focus on what happened and why it happened, and on what pupils think actually happens when coffee, salt, and a Condy's crystal dissolves in water.

In our experience many pupils consider (see p. 8) that simply on dissolving the "taste comes out" (coffee/salt) or the "colour comes out". In each case either the actual solid, or particles of the solid, cease to exist or remain as solid pieces. For example many pupils argue that the crystal in water simply loses its colour to the water becoming a paler purple.

Such ideas can be tested out, and pupils with guidance can devise experimental situations to test them out, e.g. placing one of two identical crystals in water and taking the crystal out when partly dissolved to see if it is smaller or if it is the same size but not so dark as before.

The ideal situation which we believe should occur is for the teacher to adopt the role of team leader of a group of scientists; influenced in what investigations are to be carried out by good sensible suggestions from his less experienced scientific colleagues (the pupils). The above basic investigations on dissolving provide an ideal context in which to develop this situation.

More Guidance: If you, or the class situation, means that it is not possible to provide sufficient focus to a number of different group activities for you to feel worthwhile learning will occur, it may be necessary to involve the whole class in considering alternative views and together plan an investigation.

For example, after discussing the various views about what is happening when a crystal dissolves in water, it may be possible to group pupils ideas under two or three main viewpoints. For example

(a) The crystal breaks open, or the surface is somehow effected, so that colour contained within the crystal leaks out. The colour spreads out, leaving the crystal or the bulk of the crystal behind.

(b) The crystal consists of nothing but the particles, these particles steadily break off the crystal surface making the crystal smaller. The tiny particles in the water make the water look purple.

The class can then design and carry out an investigation to decide which view is more sensible.

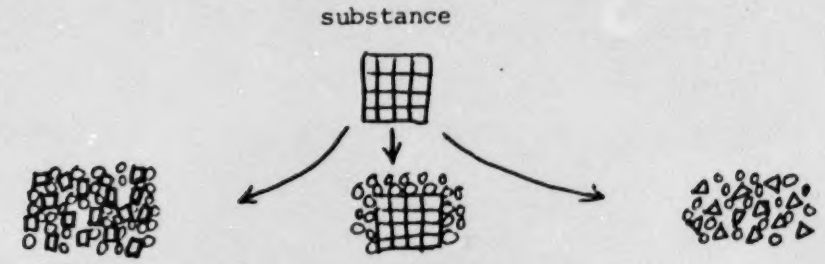
Further Considerations: The dissolving of salt and/or Condy's crystals lead to a wealth of possible investigations which pupils could design, get approved by you as the teacher, and then be carried out by the pupils. Does the water temperature change as things dissolve? How much salt can you dissolve in a set amount of water? Does this depend on the water temperature? What happens when salty water is heated? (many pupils believe both water and salt will evaporate together).

Were These Chemical Reactions? To complete this unit of work we need to focus on whether or not a chemical reaction was involved in the dissolving process. The reversibility of the dissolving process (a question looked at under further considerations above), the lack of heat being produced, significant colour change. None of these things guarantee that we do not have a chemical reaction and we would have to do more complicated checks as to whether new substances have formed. However we can account for all we can observe by assuming no chemical reaction has occurred!

5.11: A THEORETICAL REVIEW

As a final discussion which might help to clarify the ideas developed in this paper, teachers might like to explore with pupils the range of possible things that can happen when a substance is placed in water or heated. These are two common situations which will enable ideas to be elaborated and reinforced. Specific examples of the various possibilities should be demonstrated and discussed.

(a) A substance is placed in water:

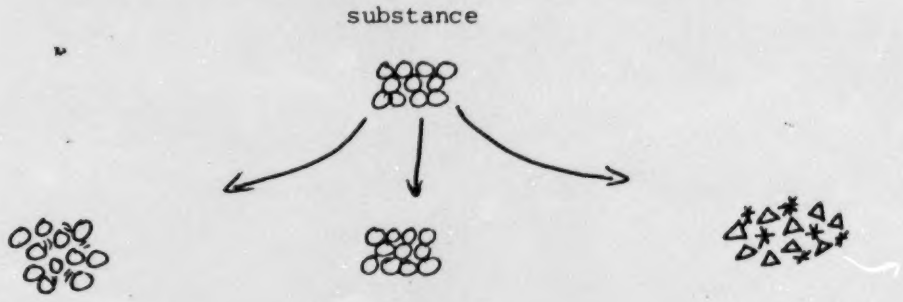


the substance dissolves
e.g. sugar

the substance does not dissolve
e.g. sand

the substance reacts
e.g. calcium

(b) A substance is heated:



the substance melts
e.g ice

nothing appears to happen (but the particles move round more and spread out slightly
e.g. metal

a new substance or substances are formed (a chemical reaction occurs)
e.g. sugar, bread

Finally, after completing this unit, you could use the survey again after a break of several weeks. Use the responses given for further teaching where appropriate.